PERMO-CARBONIFEROUS CONDITIONS VERSUS PERMO-CARBONIFEROUS TIME

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Although the "red beds" of the late Paleozoic and other deposits of equivalent age have long been called Permian in North America, evidence is steadily accumulating to show that the true Permian is absent or nearly so, in the United States, and that the beds formerly so called are better regarded as of Permo-Carboniferous age.

Under one or the other of these names there have been included in the eastern part of the United States all the Paleozoic deposits above the base of the Dunkard formation in Pennsylvania, West Virginia, and Ohio, and possibly the upper beds of the Boston and Narragansett basins, the Paleozoic deposits of Nova Scotia and New Brunswick above the base of the New Glasgow conglomerate, and practically all of the red deposits of Prince Edward Island.

In the western part of the United States the same horizon is believed to begin with the base of the Elmdale formation of Kansas and its equivalents, both east and west of the Rocky Mountains.

The discovery of vertebrate fossils belonging to identical or closely related genera and the evidence of fossil plants have led to the suggested correlation of the red beds of Kansas, Oklahoma, Texas, and New Mexico with the Dunkard of Ohio and Pennsylvania, and the isolated deposits carrying vertebrate fossils near Danville, in Vermilion County, Illinois. Such suggestions of correlation, however, do violence to the probabilities indicated by the stratigraphic position of the beds in which the fossils are found. It is the purpose of this paper to point out what seems to be a more rational method of correlation, which will reconcile the evidence from fossils with that from the stratigraphy.

Correlation of widely separated horizons must be largely accomplished upon the evidence furnished by fossils, but, as is

becoming increasingly evident to all workers in stratigraphy as well as paleobiology, fossils must be regarded and interpreted as once living things, and the problem of their distribution is inextricably associated with the problem of their living conditions. The method of evolution is as yet undetermined, but all biologists concede the directive influence of environment when a line is once started, by whatever means it was originated. In other words, evolution of life follows and responds to change, or evolution, in the inorganic environment. If this be true, the beginning of a new geological interval of time is marked by the change in the inorganic world which will lead by slow degrees and a multiplicity of processes to the development, or immigration into a definite area, of new forms of life. The new interval begins with the establishment of new conditions fitted for the new life and may precede by a very considerable period of time the establishment of the new life in such abundance as to be recognized as constituting a new fauna, faunule, or flora. On the other hand, it is very possible that the establishment of new conditions may be almost immediately followed by the introduction of a new fauna or flora, as by immigration. These ideas are in strict consonance with the determination of geological intervals on the principle of diastrophism.

If any progressive criteria can be detected and traced which reveal such a change in the inorganic world, then the evidence of the organic world may be better interpreted and even in some measure anticipated. Changes in the inorganic world are in general more obvious under terrestrial conditions than under marine, but a change from marine to terrestrial conditions would be the most obvious of all.

The more evident and violent effects of diastrophism are readily detected and their results easily interpreted, but where the change is a slow and gentle one with slight disturbance of the rock layers and, as in a case of slow elevation, with a resultant destruction of the surface beds and sparse deposition of terrestrial sediments, the problem becomes far more intricate. In such a case it is sometimes necessary to turn to more obscure and commonly neglected factors, such as the climatic alteration resulting from change of altitude and exposure of large areas of land.

It is just this factor of climatic change that the author proposes to use in the interpretation of the change of environment in late Paleozoic and as a basis for the correlation of "Permo-Carboniferous conditions" as opposed to a correlation of a certain group of beds within definite stratigraphic limits. "Permo-Carboniferous conditions," as here used, involves the idea of an interval of time, but not of the same duration in all areas where such conditions prevailed, for, as will be shown, the conditions were developed progressively across a large area and the base of the deposits governed by such conditions cut obliquely across the stratigraphic column. In the case here discussed the shape of the deposits so governed is that of a flat wedge, for the conditions persisted where they were

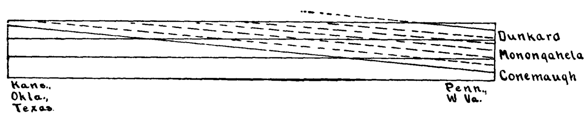

FIG. 1.—Diagrammatic illustration of the relation of "Permo-Carboniferous conditions" to the late Paleozoic stratigraphy. No account is taken of the breaks or the present geological structures. The dashed area indicates "Permo-Carboniferous conditions."

first established and the progress of the conditions led to ever thinner deposits toward the outer limit (see Fig. 1). It is conceivable that under other circumstances a uniform set of conditions might pass across a large area as a wave, and the resultant deposits would then be detected in the stratigraphic column as a band of greater or less thickness oblique to the normal bedding-plane.

As shown in the abbreviated correlation table below, the Dunkard with its typical Permo-Carboniferous flora, fauna of invertebrates, and single characteristic vertebrate (*Edaphosaurus*) is by all commonly accepted canons of correlation and by its stratigraphic position the very approximate equivalent of the Wichita-Clear Fork beds of Texas, but both red beds and Permo-Carboniferous vertebrates are found far below this horizon in both Pennsylvania and West Virginia. In Pennsylvania, Raymond found vertebrates closely similar to those occurring in Texas in the Pittsburg Red Shale, 500 feet below the top of the

ABBREVIATED CORRELATION TABLE OF THE LATE PALEOZOIC

Texas	Oklahoma	Kansas	Indiana	Pennsylvania and West Virginia	Massachusetts	Rhode Island	New Brunswick
Absent or red deposits in the panhandle	Quartermaster and Greer	Cimarron					
Double Mountain	Woodward	Wellington		Dunkard	Roxbury conglomerate (Squantum tillite)	Dighton conglomerate	New Glasgow conglomerate
Clear Fork	Blaine	Marion					
Wichita*	Enid	Chase					
		Garrison	Merom sandstone				
		Waubunsee					
Cisco	Ralston (Chandler)	Shawnee	Coal VIII	Conemaugh	Dorchester slate	Rhode Island formation	Shulie formation

*Permo-Carboniferous conditions began approximately at the time indicated by the heavy lines in the table.

Conemaugh. In West Virginia, Hennen found the cast of a bone comparable only with *Pareiasaurus* in red shales about 200 feet below the base of the Monongahela series.

Dr. I. C. White has long contended that the sudden appearance of the red sediments in the Conemaugh marks the beginning of a new geological period with changed conditions of environment and sedimentation. The red deposits continue in Pennsylvania and West Virginia more or less dominantly to the top of the Dunkard. Farther to the north the red sediments, tillites of the Boston basin, the New Glasgow conglomerate and the red conglomerates, and shales and sandstones of Prince Edward Island are certainly well up in the late Paleozoic. Sayles and Mansfield have demonstrated the glacial origin of the Squantum tillite, and Bell has shown that the New Glasgow conglomerate is due to an elevation somewhere to the southeast.

These local proofs of elevation are but contributory evidence of the commonly accepted elevation of the whole eastern part of North America, probably as a continuation of the same movement which formed the Hercynian chain somewhat earlier in Central Europe. The elevation of North America which began on the eastern side was gradually extended to the west, as is shown by the progressive disappearance of the Mississippian sea and the Pennsylvanian coal swamps in that direction.

The elevation was attended by a gradual change in climate; instead of gray and black shales and white sandstones the prevailing deposits were colored red by the oxidation of the iron under the influence of a less equable climate, as seasons of relative drought and humidity succeeded each other.

As this climatic change migrated toward the west only slowly, red sediments were formed at progressively higher and higher levels. In western Kentucky, Indiana, and Illinois the conditions necessary for the formation of red beds did not arrive until after the highest sediments now preserved had been formed, or only thin deposits were formed which have since been removed by erosion. That the surface on these regions was dry land by the time "Permo-Carboniferous conditions" (formation of red beds) had reached them is suggested by the mode of occurrence of the vertebrates in Illinois and the Merom sandstone in Indiana.

Beyond the elevated region of Missouri the upper Pennsylvanian and Permo-Carboniferous rocks of Kansas are limestones and gray to black shales, but farther south the Permo-Carboniferous beds of Oklahoma, Texas, and New Mexico are red. These beds lie above the Missourian of Missouri and Iowa which extend well up toward the top of the Pennsylvanian, as developed in Pennsylvania and West Virginia, certainly much higher than the first appearance of red beds in the Conemaugh series in those states.

The appearance of red beds is generally accepted as evidence of a decided climatic change and it is also generally accepted that this change in the late Paleozoic was largely the result of an elevation of the continent which began in the eastern side and progressed toward the west, though other causes, as a change in the amount of CO_2 in the air, very probably had some part in the final result.

As stated above, red beds appear at successively higher levels toward the west. Detailed evidence for this will be given in a forthcoming monograph in the publications of the Carnegie Institution of Washington.

As the uplift affected regions farther and farther to the west, the climate altered progressively in the same direction and the resultant changes in physiography, hydrography, and vegetation compelled an alteration of the environment which permitted the migration of the Permo-Carboniferous reptilian-amphibian fauna with but little morphological change.

This environment remained fixed in the east as it spread westward, resulting in a wedge-shaped series of beds which can be correlated as formed under "Permo-Carboniferous conditions" from the observed effects produced by climatic factors. The wedge shape of this series causes it to extend deeply into the Pennsylvanian series (to middle Conemaugh) in the east and to involve only the true Permo-Carboniferous in the west. The development and migration of the vertebrate life were governed, not by the passage of geological time, but by the development and spread of the peculiar environment.

The occurrence of Permo-Carboniferous reptiles and amphibians much lower in the stratigraphic series on the east than on the west is no longer a puzzle. The animals appeared with the environment and migrated with it. They occur strictly within the time and

limits of "Permo-Carboniferous conditions" at every place where they are known.

The sequence in the evidence of the progressive development of the red bed westward is broken in two places by the elevation at the Cincinnati anticline and at the elevation in Missouri. An effort has been made to trace the beds around these elevations, but as yet with indifferent success. The breaks are in part due to the effects of erosion removing all traces of Permo-Carboniferous deposition and in part to the fact that these lands were elevated above the plane of deposition before the climatic migration had reached them.

An apparent conclusion from the premises here stated is that the Permo-Carboniferous vertebrate fauna originated in the eastern part of North America and migrated westward. This the author is not yet entirely ready to accept, and yet he is strongly impelled toward that conclusion by the facts that the earliest known reptile was discovered in the Allegheny series, at Linton, Ohio; that typical Permo-Carboniferous vertebrates appeared in middle Conemaugh time in Pennsylvania and West Virginia, and that typical Pelycosaurs occur in the red beds of Prince Edward Island at a stratigraphic level much lower than those of Oklahoma and Texas.

The theses of this paper are:

1. That environment is the determinant factor in the development and spread of a fauna.

2. That an environment favorable to a certain group may develop and migrate, involving different levels of one or more geological epochs.

3. That a fauna or flora may be correlated as belonging within the limits of such an environment independent of stratigraphic levels.

4. That the limits of such an environment may be detected by various lines of inorganic evidence. In the case of the development and spread of "Permo-Carboniferous conditions" the effect of climate furnishes the observable limits.

Further evidence for the statements made in this paper and more extended treatment of the subject will be given in a monograph of the Carnegie Institution of Washington dealing with the environment of life in the late Paleozoic.